District Energy Inventory for Canada, 2014

Prepared for:
CanmetENERGY, Natural Resources Canada
Environment Canada and
CIEEDAC Supporters

Prepared by:
John Nyboer
Bradford Griffin

of the
Canadian Industrial Energy End-use Data and Analysis Centre
Simon Fraser University, Burnaby, BC

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About CIEEDAC

The Canadian Industrial Energy End-use Data and Analysis Centre (CIEEDAC), established in 1993 by Natural Resources Canada, primarily focuses on energy information relevant to Canada’s industrial sector. One of CIEEDAC’s primary goals is to expand and improve the existing knowledge on energy use by establishing processes for the regular and timely collection of reliable data in areas and sectors where data gaps exist, including data on cogeneration, renewable energy and, as is the focus of this report, district energy. CIEEDAC provides a range of services to industry and government, one of which is the preparation of annual reports that present the latest data on energy use and related issues for the Canadian industrial sector and those sectors mentioned above. These data can be obtained from CIEEDAC’s online databases.
Executive Summary

The 2016 District Energy Inventory for Canada (2014 data) presents an updated snapshot of the thermal energy network across the country. We have identified 159 operating district energy systems across the country (up from 128 last year), increasing the comprehensiveness of our inventory. To date, detailed data have been gathered from 80 facilities (up from 67 last year), providing deeper insight into the nature of district energy systems in Canada. These data enable us to better analyze the types of service provided, governance structures, district energy customers, a variety of operating data, recent and/or planned growth and facility employment.

This year, CIEEDAC updated and expanded the questionnaire to improve ease of use and capture additional details on fuel consumption, employment growth and industry investment.

The development of this inventory fills a gap in the reporting of information about district energy systems. Moving forward, CIEEDAC and its partners plan to administer the district energy questionnaire on a regular basis to keep information current (possibly having an annual survey related only to fuel use and energy supplied, with a less frequent but more detailed questionnaire), develop relationships with the respondents to boost the response rate, investigate additional research questions and present more regional and disaggregated information.

What is district energy?

A District Energy System (DES) is a system designed to supply thermal energy (and possibly electricity) to multiple buildings from a central plant or from several interconnected but distributed plants.

Key findings of the report include:

- **Ontario and British Columbia have the greatest number of systems.** Of the systems we identified, 44 are in Ontario and 42 are in British Columbia, together accounting for more than half of all systems in Canada.

- **District energy facilities provide a range of services, including heating, cooling and electricity.** Almost half of all facilities offer heating only; one-third offer heating and cooling; and one-fifth offer electricity through cogeneration with heating and/or cooling.

- **District energy facilities serve a range of customers.** Most facilities (75%) serve more than one customer type. Some of the most common customer types include commercial and institutional buildings, community and recreational facilities, government offices and educational facilities.
• The data show a recent surge in the construction of district energy facilities. Half of all facilities have been commissioned since 2000, with one-quarter of all facilities constructed in the past five years.

• The main investment sources for district energy facilities appear to be utilities, local government, senior government, and institutions. The shares for each of these investors are fairly similar (23% to 30% of facilities). While the majority of systems have an estimated market value of less than $10 million, almost one-quarter are estimated at over $50 million.

• District energy facilities use a wide variety of fuels. Facilities reported using gaseous and liquid fossil fuels, biomass, geoxchange, electricity, surplus heat from industrial processes, energy extracted from waste water effluent, sea and lake water for cooling, municipal solid waste and solar energy.

• District energy facilities reported serving a total of 2,863 buildings. The average number of buildings served is 37. The largest number of buildings served by a single facility is 302.

• The total annual thermal energy delivered by these heating and cooling systems is approximately 5.9 million MWh. This energy accounts for about 1% of the total building energy use for space heating, space cooling and water heating in Canada. This figure underestimates the contribution of district energy because it does not account for facilities that did not respond to the questionnaire.

• Compared to the average emission factor for fossil fuel based systems, the use of renewable energy avoided 7% of the GHGs that would have otherwise been emitted. However, the currently available data are insufficient to conduct a further analysis of the energy and GHG savings that could be attributed to the use of district energy.

• Almost two-thirds of facilities require fewer than five full-time equivalent positions. However, almost one-third require more than 10 positions. Facilities consuming primarily fossil fuels tend to employ a larger number of employees and most of the facilities with greater than 10 employees are fossil fuel-based.

• The majority of facilities report planning some level of expansion to their operations in the future. Planned expansions include increases to installed generation capacity, size of distribution network, and number of end user connections. Where anticipated growth exists, it is likely to be highest over the next two years.

Data presented in this report are also available in an online database maintained on the CIEEDAC website: www.cieedac.sfu.ca.
Acknowledgments

This project would not have been possible without the district energy plant system owners and operators who took the time to complete the questionnaire distributed as part of this project.

CIEEDAC wishes to thank Natural Resources Canada's CanmetENERGY for providing funding and support for this project. CIEEDAC also wishes to thank Environment Canada, who supports the work of CIEEDAC though their ongoing sponsorship and financial contributions, and its many industry association supporters, particularly those which have an interest in district energy as part of their member’s activities.

This project was undertaken with the financial support of the Government of Canada.
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1 Introduction

1.1 Objectives and Purpose

This report presents the results of CIEEDAC’s third annual district energy questionnaire, which is enabling us to construct a Canada-wide inventory of district energy systems. This inventory should be of interest to those seeking to establish or expand manufacturing, engineering and other related services to the district energy industry, as well as to decision makers who develop policies and programs affecting the district energy industry.

In the 2016 District Energy Inventory for Canada, we present a snapshot of the thermal energy network across the country. The development of this inventory fills a gap in the reporting of information about district energy systems, and CIEEDAC and its partners plan to administer the district energy questionnaire on a regular basis to keep information current (possibly having an annual survey related only to fuel use and energy supplied, with a less frequent but more detailed questionnaire).

The specific objectives of this report are to:

1. Provide an overview of the known systems operating within Canada, including their location and principal characteristics like system size and fuel type.
2. Conduct an analysis of Canadian district energy systems, identifying them by province, fuel type, technology, operating parameters and their contribution to the Canadian energy economy.

1.2 A Brief History of District Energy

District energy systems supply thermal energy, and sometimes electricity, to multiple buildings from a central facility. Such systems can be traced back to the Roman Empire, where hot water was transferred among buildings.

Canada’s first district energy system was developed in the 1880s in London, Ontario to distribute heat to neighbouring government, university and hospital facilities. Since that time there have been two distinct spikes in district energy activity in Canada.

The first spike of activity occurred in response to the oil crisis in the 1970s. The oil crisis had a similar impact on the development of district energy systems in Europe, spurring growth in many countries and establishing a legacy of district energy infrastructure that is still in operation today. Early success and continued experience with district energy systems in Europe has helped to grow Canada’s district energy market.

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1 A complete definition of district energy systems used in this survey is included in Section 2: Methodology.
In the late 1990s and early 2000s, Canadian district energy experienced another spike in development due to technological improvements and government support. Historically, district energy systems were less efficient and powered by fossil fuels, which produce local air pollution and greenhouse gas emissions. However, today’s district energy plants are much more efficient and utilize a range of alternative locally available energy sources such as biomass, solar energy, deep-water cooling and solid waste, producing much less pollution. In addition to its potential environmental benefits, district energy can also provide a secure supply of energy at low cost.

1.3 Report Outline

This report is structured as follows. In Section 2, we describe the methodology employed to create the questionnaire and inventory. In Section 3, we present results from the questionnaire, which are broken down into a variety of sub-sections, including: system information, governance, community context, operating data and employment. Section 4 presents the conclusions, including recommendations for future research.

Data presented in this report are also available in an online database maintained on the CIEEDAC website: www.cieedac.sfu.ca.

Regional analysis text boxes

Throughout the report, additional information describing important trends among regions in Canada is presented in text boxes like this one. In future reports, CIEEDAC will work with its funding and industry partners to improve the comprehensiveness of the district energy results and the regional analysis.
2 Methodology

The District Energy Inventory was developed in two distinct phases. The first phase involved updating and expanding the questionnaire, identifying district energy systems to be contacted for updated or new information, and finally distributing questionnaires pre-populated with existing data to owners and operators of those systems. The second phase involved validating responses to ensure data integrity and analysing the data. These phases are discussed in more detail below.

2.1 Questionnaire Update and Expansion

The questionnaire content was originally developed with the participation of the former Canadian District Energy Association and Natural Resources Canada’s CanmetENERGY. It was designed to be simple and easy to complete – the result of feedback from a broad cross section of industry representatives. This year, CIEEDAC updated the questionnaire to improve clarity and usability, and establish more robust confidentiality protocols. The questionnaire was also expanded to capture new or updated data for the following areas of interest:

1. **Industry Investment**: To advance the development of district energy in Canada, there is great advantage to understanding current investment regimes and the impact that private investment may have on future DE development.

2. **Operating Temperatures and Thermal Storage for Heating (Water)**: Operating temperatures of different systems can vary widely. Knowledge of temperatures will enable improved system comparisons and assessment of the potential for introducing alternative energy supply sources and greater use of thermal storage.

3. **Energy Use**: Fuel use data are collected in order to better evaluate GHG emissions generation and allow for a comparison between fossil fuel and renewable energy based systems.

4. **Change in Employment**: Industry employment levels provide an additional parameter for assessing industry size and rate of growth. Change in employment over the last five years and expected growth for the next five years add to a fuller picture of the district energy industry’s development.

2.2 Contact List Development

An updated contact list to identify new or previously non-responsive district energy plants was developed based on information provided by Natural Resources Canada and by cross-referencing other databases and sources of information, including previous
Canadian District Energy Association (CDEA) surveys, the QUEST Smart Energy Map,³ the CIEEDAC cogeneration database, a list of operating and former CDEA members. We have also reached out through our professional contacts and will continue to do so in the future to expand the list. Our current list identifies 159 facilities, up from 128 identified last year.

The systems included in the database are all operational and meet our definition of district energy (see box on the following page). Generally speaking, we consider systems to be district energy if the energy provided for water heating and space conditioning service more than one building. We do not consider systems inside the "plant gate" to represent district energy, because many such facilities use energy for processes other than space conditioning and water heating.

2.3 Questionnaire Distribution

While last year’s questionnaire was administered online in a Drupal-based format, this year’s questionnaire was redesigned as an excel spreadsheet to improve usability and be more consistent with the data collection procedures used for CIEEDAC’s cogeneration and renewable energy databases. Questionnaires pre-populated with existing data for all facilities already captured in the database were sent out electronically in November and early December, 2015. Questionnaires for new or previously non-responsive facilities were distributed in December 2015 and January 2016. Reminder emails and follow-up were conducted in January and February, 2016.

This year’s exercise was a test cycle, a first step to a much more automated process. In the future, the questionnaire will be automatically populated and distributed and allow the respondent to update data reflecting their facility at any time.

³ http://www.questcanada.org/themap
District Energy System Definition

A District Energy System (DES) is designed to supply thermal energy for space conditioning and water heating (and possibly electricity) to multiple buildings from a central plant or from several interconnected but distributed plants. In industrial applications, energy must be supplied to buildings outside the plant gate in order for the system to be considered district energy. Systems that are self-contained within institutional campuses such as hospitals, universities, and military bases, and that supply more than one building, are also considered district energy.

A DES is comprised of the following:

- **A thermal energy plant(s)** that generates thermal energy for end-user buildings, and may also co-generate electricity for the electric grid or for use by specific buildings or processes;

- **A thermal distribution network** of interconnected pipes that transports the thermal energy from the plant(s) to end-user buildings using hot water, chilled water, or steam; and

- **An end-user building interface** to transfer the thermal energy from the working fluid to the buildings’ heating and cooling systems, and if necessary, to measure the quantity of energy transferred.

A DES will also have a defined operational structure for system management and control, as well as an administrative structure for customer billing where necessary.

2.4 Data Validation and Analysis

Of 159 identified systems, we were able to make contact with and administer questionnaires to 103. To date, 42 responses have been received, of which 9 were for new facilities. This brings the total number of facilities with detailed data captured in our database to 804, up from 67 last year. While not all responses were complete, the overall response rate of 50% from known systems is high relative to other comparable surveys, reflecting CIEEDAC’s efforts to follow up with owners and operators.

All responses were reviewed for errors and substantive omissions. Critical errors, for example, logical inconsistencies such as energy supplied exceeding stated plant capacity, were resolved by contacting the respondents. In many cases, these problems related to incorrect unit conversions. Responses to survey questions also provided CIEEDAC analysts with information that will improve the survey for the future.

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4 Includes facilities not currently in operation.

The data analysis phase involved transforming the responses into a meaningful description of the state of district energy in Canada, the results of which are presented in the following section.

In 2014, the District Energy database was harmonized with two other databases housed at CIEEDAC, the Cogeneration database and the Renewable Energy database. There is, for example, at least one district energy facility that would fit into all three databases because it serves its clients with both electricity and heating / cooling using renewable energy. At least 12 district energy systems cogenerate and at least 30 utilize renewable energy (biomass, geothermal or solar). In order to ensure consistency between the three datasets, funds were obtained to harmonize them such that there would be no conflict regarding facility details.

The data presented in this report are available in an online database maintained on the CIEEDAC website: www.cieedac.sfu.ca.
3 Questionnaire Results (2014 data)

3.1 System Information

Number of facilities

Figure 1 shows the number of recognized systems in each province and territory. In total, responses from 77 facilities have been received out of a total of 159 known facilities. CIEEDAC is working with its industry and funding partners to improve database coverage over time and was expecting to obtain responses from a number of facilities prior to our publication release deadline.

Figure 1: Facilities by province/territory

Services provided

Close to half of the facilities (34) offer heating only (see Table 1). A little over one third (28) offer heating and cooling, while 15 facilities offer electricity through cogeneration with heating and/or cooling.

Table 1: Facilities by combination of services provided

<table>
<thead>
<tr>
<th>Services provided</th>
<th>Number of facilities</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating only (water and/or steam)</td>
<td>34</td>
<td>44%</td>
</tr>
<tr>
<td>Heating (water and/or steam) and cooling (water)</td>
<td>28</td>
<td>36%</td>
</tr>
<tr>
<td>Electricity from a combined heat and power facility</td>
<td>15</td>
<td>19%</td>
</tr>
<tr>
<td>with heating and/or cooling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>77</td>
<td>100%</td>
</tr>
</tbody>
</table>

Figure 2 shows the number of facilities that offer heating, cooling and electricity. Since many facilities offer more than one service, the total adds up to more than the 77 responses received. Roughly three-quarters of facilities polled offer heating using water...
(59) and half offer cooling (37). Slightly fewer offer heating through steam (31) and electricity through combined heat and power (15).

Figure 2: Facilities by type of service provided

![Facilities by type of service provided](image)

3.2 Governance

*System ownership*

Table 2 describes the district energy facilities by system owner. Institutional ownership, such as through academia or healthcare, accounts for the largest share of district energy ownership (28% of facilities). Over 20% are owned each by private corporations and municipal governments.

Table 2: Facilities by system owner

<table>
<thead>
<tr>
<th>System owner</th>
<th>Number of facilities</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutionally owned, either by academia, healthcare, or other institutional body</td>
<td>21</td>
<td>28%</td>
</tr>
<tr>
<td>Private Corporation owned</td>
<td>17</td>
<td>22%</td>
</tr>
<tr>
<td>Municipal Government Owned</td>
<td>16</td>
<td>21%</td>
</tr>
<tr>
<td>Federal Government Owned</td>
<td>8</td>
<td>11%</td>
</tr>
<tr>
<td>Provincial Government Owned</td>
<td>5</td>
<td>7%</td>
</tr>
<tr>
<td>Public/Private Partnership, owned by both a corporation and a government body</td>
<td>2</td>
<td>3%</td>
</tr>
<tr>
<td>Public Corporation owned, where shares can be sold on stock exchanges</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>Cooperative Ownership</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>Other</td>
<td>5</td>
<td>7%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>76</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

A range of other system owners account for the remaining 29% of systems: federal, provincial and First Nations governments, crown corporations, cooperatives, public corporations and public/private partnerships. The majority of respondents describe
themselves as both the system owner and operator (88% of respondents). The remaining respondents identify themselves as system owners or operators.

**Regional focus: Services provided**

Figure 3 shows the number of facilities providing each service by region. British Columbia has the greatest number of heating with water systems, while Ontario has the greatest number of all other system types.

**Figure 3: Facilities by services provided and region**

![Facilities by services provided and region](image)

*Regions aggregated to maintain system confidentiality (AT=Atlantic).

### 3.3 Investment

The 2016 questionnaire included questions about the types of investor and estimated market value of each district energy system’s assets. The response rate for the type of investor was quite good at 46 responses or 90%, however, there were fewer facilities willing to indicate the value of their system assets (23 response or 55%).

From the responses received, we see that most district energy facilities received at least some funding from senior government (37%) and local or municipal government (29%), and institutions (24%). Some facilities received investment from more than one source, so the total shares add up to greater than 100%.
Possible investment sources were inferred for those facilities that responded to the CIEEDAC questionnaire in previous years, but did not do so for the 2016 questionnaire. Inferences were based on the facility’s name, governance structure, customer description, and supporting material such as website information. The majority of additional investment sources were inferred to come from utilities, institutions, and government. When combined with the questionnaire responses, the main investment sources appear to be utilities, local government, senior government, and institutions. The shares for each of these investors are fairly similar (23% to 30% of facilities).

The majority of the district energy facilities that responded (23 total) have system assets with an estimated market value below $10 million (14 facilities or 61%). Most of these facilities are well below the average and median in terms of heating and cooling capacity, area served, and trench length. Large variation exists within this category with facilities serving from 2,000 m² up to 1.7 million m². Accordingly, a finer disaggregation in future questionnaires may be appropriate for the smaller investment range. Almost one-quarter (5 facilities or 22%) of facilities have an estimated market value of greater than $50 million.
3.4 Community Context

*Municipality size*
Over half of facilities (39 or 51%) are located in large population centres with more than 100,000 people (see Figure 6). Most of the remaining facilities are located in medium (30,000 to 99,999 people) and small population centres (1,000 to 29,999 people). Only 6 facilities (8%) are located in rural municipalities (fewer than 1,000 people).

*Figure 6: Facilities by size of municipality*
**Types of customers**

District energy facilities serve a range of customers. Most facilities (75%) serve more than one customer type (see Figure 7). Table 3 describes the type of customers served by surveyed facilities in more detail. Almost 90% of facilities serve a commercial or institutional end-user, such as offices, commercial space and cultural buildings. Over 70% percent serve a community centre or recreational facility; and 70% serve government, including office space or other public services such as fire and police stations. Over 70% of facilities serve an educational end-user and 57% percent of facilities serve residential buildings. At least 22 systems serve military facilities, although most of these have not yet been incorporated into the database.  

*The data are forthcoming but were not available before the publication of this document.*

![Figure 7: Number of customer types served by each facility](image)

**Figure 7: Number of customer types served by each facility**

<table>
<thead>
<tr>
<th>Type of customers/End-users served by the system</th>
<th>Number of facilities serving each customer type</th>
<th>Share of facilities serving each customer type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial/Institutional</td>
<td>66</td>
<td>87%</td>
</tr>
<tr>
<td>Community Centre/Recreation Facility</td>
<td>55</td>
<td>72%</td>
</tr>
<tr>
<td>Government/Public Service</td>
<td>53</td>
<td>70%</td>
</tr>
<tr>
<td>Education</td>
<td>54</td>
<td>71%</td>
</tr>
<tr>
<td>Healthcare</td>
<td>24</td>
<td>32%</td>
</tr>
<tr>
<td>Residential</td>
<td>43</td>
<td>57%</td>
</tr>
<tr>
<td>Other* (including military bases)</td>
<td>21</td>
<td>28%</td>
</tr>
</tbody>
</table>

* Aggregated to maintain confidentiality.

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6 The data are forthcoming but were not available before the publication of this document.
3.5 Operating Data

The questionnaire collected a range of operating data about district energy facilities, including facility age, fuels used, use of thermal metering, physical dimensions (number of buildings served, floor space and trench length), installed capacity, energy delivered and peak load. We discuss these characteristics below. Detailed operating data are provided in the Appendix.

Facility age

Figure 8 categorises facilities by the year they were first commissioned. The data show a recent surge in the construction of district energy facilities, with just over half of all facilities commissioned since 2000. Interestingly, almost half of those recent facilities were commissioned between 2011 and 2014.

Another peak construction period is apparent between 1960 and 1980, with close to 20% (15) of facilities being commissioned during this period.

Figure 8: Facilities by year first commissioned

![Bar chart showing facilities by year first commissioned](chart.png)
Regional focus: Facility age

The majority of construction has occurred in British Columbia and Ontario, with these two provinces accounting for almost 60% of the total systems (see Figure 9). The Territories, a region which didn’t have any district energy facilities prior to 1980, and British Columbia have seen almost all of their facilities constructed since 2000, while the other provinces continue to have a higher share of older systems.

Figure 9: Facilities by year first commissioned and region

Thermal metering

Figure 10 describes the proportion of facilities using thermal metering for individual customers and end users for heating with steam, heating with hot water and cooling. The majority of facilities use thermal metering for each service, although the share is highest (77%) for heating with steam. Thermal metering is less frequently used in facilities that provide hot water and cooling (54-60%).
Number of buildings, floor space served and trench length

The total number of buildings served by facilities responding to the questionnaire is 2,863 (Table 4). Each facility serves an average of 37 buildings, although this statistic is skewed by several facilities that serve a large number of buildings (up to 302). The average floor space is 470,000 m² and average distribution system trench length of all facilities is 4.5 km. As more facilities are added to our database these statistics tend to come down, since newly added facilities are generally smaller, previously unidentified district energy systems.

Table 4: Summary of physical characteristics for all systems

<table>
<thead>
<tr>
<th>Units</th>
<th>Number of buildings served</th>
<th>Total floor space area served</th>
<th>Total distribution system trench length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>1000 m²</td>
<td>km</td>
</tr>
<tr>
<td>Average</td>
<td>37</td>
<td>470</td>
<td>4.5</td>
</tr>
<tr>
<td>Median</td>
<td>12</td>
<td>76</td>
<td>2.4</td>
</tr>
<tr>
<td>Minimum</td>
<td>2</td>
<td>2</td>
<td>0.1</td>
</tr>
<tr>
<td>Maximum</td>
<td>302</td>
<td>5,576</td>
<td>35.0</td>
</tr>
<tr>
<td>Sum total</td>
<td>2,863</td>
<td>31,002</td>
<td>347.6</td>
</tr>
<tr>
<td>Number of responses (n)</td>
<td>76</td>
<td>64</td>
<td>75</td>
</tr>
</tbody>
</table>
Regional focus: Floor space by region

Figure 11 describes the floor space served by district energy systems in each region. District energy systems in Ontario serve the largest amount of floor space - almost 14 million m² – followed by British Columbia with about 6.6 million m².

**Figure 11: Floor space served by region**

![Bar chart showing floor space served by region](chart.png)

*Regions aggregated to maintain system confidentiality (AT = Atlantic).

**Capacity**

The total thermal capacity reported by district energy facilities is 5,226 MW and the total electrical capacity is 125 MW. However, facilities range greatly in capacity. Figure 12 shows the distribution of facilities by rated capacity. Almost one-quarter (1,190 MW or 23%) of thermal capacity comes from just two plants that provide steam. Electrical capacity tends to be much lower, with the largest system rated at 21 MW (and an average capacity of 8 MW).
Regional focus: Heating and cooling capacity by region

Heating and cooling capacity by region is shown in Figure 13. Ontario has the highest heating capacity (1,927 MW) and cooling capacity (750 MW). Interestingly, capacity is higher in Alberta than the number of systems alone might suggest; Alberta has a smaller number of larger systems.

Figure 13: Heating and cooling capacity by region
Energy delivered

In 2014, total annual thermal energy delivered by district heating and cooling systems that reported thermal energy supplied (34 to 45 depending on energy type) reached 5.9 million MWh (21 PJ). This accounts for about 1% of the total building energy use for space heating, space cooling and water heating in Canada. About two-thirds of this was from heating with steam (3.9 million MWh). Electricity generated from combined heat and power plants was 278,440 MWh.

Figure 14 shows a distribution of facilities by their annual thermal and electrical energy output. A large range in generation exists for thermal plants. The largest three thermal plants account for over one-third of total annual thermal energy. These facilities generate hundreds of thousands of MWh every year. By contrast, nearly half of facilities surveyed have energy outputs under 10,000 MWh.

Additional metrics were developed to compare energy supplied per building, energy supplied per unit of floor space and linear heat density for different types of district energy facilities. These data are listed in the Appendix.

Figure 14: Distribution of facilities by annual generation of thermal and electrical energy

Capacity Factors

By comparing energy delivered with generation capacity, it is possible to estimate the capacity factor for each plant. Inferred capacity factors range significantly, with the

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7 According to Natural Resources Canada’s Comprehensive Energy Use Database, total energy consumption in residential and commercial/institutional buildings was 2,435 PJ in 2013. Of this, 1,890 PJ was for space heating, space cooling and water heating.

8 Linear heat density is the annual thermal energy provided to connected end-users per metre of system piping network trench.
average for steam, hot water and cooling plants to be between 11 and 25%. The highest capacity factor observed was 65% while the lowest was 3%.

A number of factors explain the apparently low capacity factors observed for some district energy facilities:

- Heating and (especially) cooling seasons are short relative to the whole year.
- Most facilities have redundancy (i.e., they may operate at about half capacity, with the rest for peak load and/or backup).
- Facilities may have plans to expand and add more customers.
- Old capital may be left as additional backup when new capital is installed.

A hypothetical example based on our discussions with questionnaire respondents illustrates the potential impact of such factors. First, if the heating season is roughly half of the year and a facility doesn’t supply water heating, utilization falls to 50%. During the heating season, a facility might operate at half of their peak output on average (utilization falls to 25%). If the facility also has a full backup, utilization drops to 12.5%. And last, perhaps the facility has replaced their main boilers but kept the old one. In this case, utilization would be well below 10%.

Of course while efforts were undertaken to validate the supplied data, it is possible that errors are still present. Future questionnaires could attempt to solicit capacity utilization data directly from facilities.

Operating temperature & Thermal storage

Questions regarding the typical summer and winter temperatures for supply and return water were included with the 2016 questionnaires. The response rate for these questions was relatively low with only 12 respondents providing temperature information. The number of facilities for various temperature ranges are shown in Figure 15. Further analysis cannot be performed until these data are expanded to cover a wider range of facilities and more thorough quality control can be performed.
Of the 14 facilities that answered the question regarding thermal storage, only one facility indicated that they use it for their operations.

**Fuel type and use**

District energy facilities use a variety of fuels, including gaseous and liquid fossil fuels, biomass, geoexchange, electricity, surplus heat from industrial processes, energy extracted from waste water effluent, sea and lake water for cooling, municipal solid waste and solar energy.

Figure 16 shows the share of facilities using each primary fuel type for base and peak load. Natural gas is the most heavily used fuel for both base and peak load, with over 40% using it for base load and almost 60% using it for peak load. Base load fuels include geoexchange (16%) and biomass (with or without other fuels; 24%), including wood chips, wood pellets and straw. The diversity of fuels used for peaking is more limited, with reliance primarily on natural gas and refined petroleum products like oil and diesel (31%).
Table 5 describes the combinations of base and peak load fuel types used for heating and cooling. Twenty-four facilities (31%) use natural gas only, with a further 9 facilities (12%) using it in combination with electricity. Eleven facilities (14%) use biomass only, predominantly wood chips or pellets, with an additional 8 facilities (10%) using biomass in combination with fossil fuels. Twelve facilities (16%) use geoexchange with or without another source of electricity. The remaining facilities use a variety of different fuel combinations.

Peak load fuels are more concentrated in a few types, with fossil fuels providing the largest shares. Natural gas (with or without electricity) is used in 41 facilities (58%); oil products (with or without natural gas) are used in 22 facilities (31%). Various other fuels make up the remaining 11% of primary fuel use.

Most facilities that offer combined heat and power use natural gas (71%). A further 14% use oil. The remaining use municipal solid waste and wood chips.
### Table 5: Combinations of base and peak load fuel types

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Base load</th>
<th></th>
<th></th>
<th>Peak load</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of</td>
<td>Share</td>
<td>Number of</td>
<td>Share</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural gas (primary)</td>
<td>24</td>
<td>31%</td>
<td>34</td>
<td>48%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural gas and Electricity</td>
<td>9</td>
<td>12%</td>
<td>7</td>
<td>10%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geoexchange and/or Electricity</td>
<td>12</td>
<td>16%</td>
<td>4</td>
<td>6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biomass (primary)</td>
<td>11</td>
<td>14%</td>
<td>4</td>
<td>6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biomass (and Natural gas or Oil)</td>
<td>8</td>
<td>10%</td>
<td>0</td>
<td>0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil (and Natural gas)</td>
<td>7</td>
<td>9%</td>
<td>22</td>
<td>31%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solar (primary)</td>
<td>1</td>
<td>1%</td>
<td>0</td>
<td>0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other*</td>
<td>5</td>
<td>6%</td>
<td>0</td>
<td>0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>77</strong></td>
<td><strong>100%</strong></td>
<td><strong>71</strong></td>
<td><strong>100%</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Includes industrial heat, wastewater, cooling water, and municipal solid waste

While only a limited number of facilities have reported their fuels used to generate thermal energy and electricity, we provide a summary looking at the fuel types, amount used and GHGs emitted in Table 6. Natural gas provides the majority of fuel used, followed by oil (and middle distillates) and biomass. When compared to the average GHG emission factor for fossil fuel based systems, the use of renewable fuels avoided 32 kt CO$_2$e, about 7% less than what would otherwise have been emitted.

### Table 6: Energy used in base and peak load and GHGs emitted

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Energy used in 2014</th>
<th>Share</th>
<th>Emission factor</th>
<th>GHGs emitted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GJ</td>
<td></td>
<td>t CO$_2$e/GJ</td>
<td>t CO$_2$e</td>
</tr>
<tr>
<td>Natural gas</td>
<td>8,084,100</td>
<td>88%</td>
<td>0.050</td>
<td>401,300</td>
</tr>
<tr>
<td>Oil and Middle distillates</td>
<td>501,000</td>
<td>5%</td>
<td>0.073</td>
<td>36,400</td>
</tr>
<tr>
<td>Biomass</td>
<td>382,500</td>
<td>4%</td>
<td>0.000</td>
<td>0</td>
</tr>
<tr>
<td>Electricity, Geoexchange, and Solar</td>
<td>177,000</td>
<td>2%</td>
<td>0.000</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>65,700</td>
<td>1%</td>
<td>0.000</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9,210,300</strong></td>
<td><strong>100%</strong></td>
<td><strong>437,700</strong></td>
<td></td>
</tr>
</tbody>
</table>

The currently available data from the survey are insufficient to conduct a more concrete analysis of the energy and GHG savings that could be attributed to the use of district energy. Values of the heating and/or cooling energy supplied are difficult to estimate at the provincial or national aggregate level, and without which comparisons to individual district energy systems are inappropriate. Many facilities in the database have energy intensities (GJ/m$^2$) greater than the provincial averages when calculated as total fuel used for heating per total floor space. This indicates that other factors may be more important when deciding whether to install or connect to a district energy system.

Further, it is unclear if large energy efficiency gains would be available from DE systems, or if the main benefits are related more to flexibility, reliability, and economies of scale.
for fuel use decisions (e.g., geoexchange systems that would not be cost effective at the individual building scale).

**3.6 Employment**

Previous questionnaires asked facilities about the number and affiliation of the people operating their systems. The 2016 questionnaire asked additional questions about the recent and planned growth in each facility’s workforce.

*Number of positions*

Most district energy systems surveyed (47 or 63%) report requiring fewer than five full-time equivalent positions. However, 22 facilities (29%) require over 10. We find that facilities consuming fossil fuels tend to employ a larger number of employees relative to facilities using renewable energy, and most of the facilities with greater than 10 employees are fossil fuel-based. Conventional facilities are likely to have higher operational and maintenance requirements than some types of renewable facilities such as geoexchange systems.

In the majority of facilities (86%), system owners hire employees to operate the facility. In most of the remaining facilities, third-party contractors are hired.

*Figure 17: Number of full-time equivalent positions per system*

*Growth*

The majority of facilities has had zero growth in the number of full-time equivalent positions over the past five years (77%) and do not plan to increase the size of their workforce in the coming five years (67%). Of the remaining facilities, 1 or 2 have seen growth of some amount over the past five years. A similar result is indicated for planned growth, with a larger number of facilities expecting a strong growth of greater than 20% in the number of full-time equivalent positions (5 facilities or 17%).
3.7 Facility Expansion

Because CIEEDAC does not execute an annual questionnaire, the data related to growth in the industry were obtained from several questionnaires. Although they are therefore not strictly comparable, we nevertheless include the responses for general information.

**Historical**

Respondents were asked to describe any growth experienced by the system over the past five years. Figure 19 summarizes these responses for generation capacity, distribution network and the number of end-user connections. Slightly fewer facilities have experienced growth in installed capacity (38%) or the size of distribution network (54%) relative to growth in the number of end user connections (61%).
Figure 19: Historical growth over past 5 years

Planned

Figure 20 describes planned growth of district energy facilities with respect to installed generation capacity, size of distribution network and number of end user connections. Most facilities report planning some level of expansion: about 60% for installed generation capacity and size of distribution network, and 71% for number of end user connections. Where anticipated growth exists, it is likely to be highest over the next two years.

Figure 20: Planned growth for next 5 years
4 Conclusions

The 2016 District Energy Inventory for Canada (2014 data) has identified 159 operating systems across the country. Of these, 42 facilities completed the questionnaire this year, bringing the total number of facilities in our database to 80 and providing us with insight into the nature of district energy systems across Canada.

Thus far, we have been able to analyze the type of services provided, governance structures, district energy customers, operating data, facility employment and investment, and recent and planned growth. This information should be helpful for those seeking to establish or expand manufacturing, engineering and other related services to the district energy industry, as well as to decision makers who develop policies and programs affecting the district energy industry.

Of course, some questions about district energy were beyond the scope of this study and remain unanswered. For example, what are the economic costs and benefits of district energy? Are there situations where district energy does or does not make sense? How much energy is saved by the development of district energy? And what role might district energy play in greenhouse gas mitigation?

Expanding the inventory could help provide insight and perspective to questions such as these. In this regard, several opportunities exist to expand and refine the database and analysis in future years. In particular, CIEEDAC can conduct a more detailed analysis by improving the inventory in a number of areas: expanding the regional reporting; exploring economic costs and benefits associated with district energy; reviewing maintenance regimes; and reviewing operating characteristics in more depth (e.g., utilization rates).

Additionally, ongoing work is required to increase the response rate of the questionnaire and improve the comprehensiveness of the inventory. In this regard, CIEEDAC will continue to make contacts with owners and operators to boost participation.

In 2014, CIEEDAC integrated and harmonized the district energy database with those for cogeneration and renewable energy. This now provides an improved contextual framework on the role of district energy and permits a better understanding of the interrelationships between district energy, renewable energy and cogeneration.

The harmonization process also included a review of the database structure of all three datasets. Each field in each data set was reviewed and its usefulness evaluated in the light of data harmonization. For example, prior to harmonization, each dataset contained facility data (facility name, ownership, contact, sector, location, etc.) and it was possible that the data in one set conflicted with another. Harmonization simplified and reduced the number of fields, ensured that energy and process definitions were the same and that data common to more than one data set (e.g., energy used) were the same.
## Appendix: Detailed Physical and Operating Data

### Table A1: Physical and operating characteristics for heating (steam) systems

<table>
<thead>
<tr>
<th>Units</th>
<th>Installed thermal capacity</th>
<th>Approximate building area served by steam</th>
<th>Trench length of steam network</th>
<th>Peak load of steam system</th>
<th>Thermal energy supplied by steam in 2014</th>
<th>Implied capacity factor*</th>
<th>Energy supplied per building*</th>
<th>Energy supplied per m²*</th>
<th>Linear heat density*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>102 MW</td>
<td>716 1000 m²</td>
<td>4.5 km</td>
<td>46 MW</td>
<td>113,263 MWh</td>
<td>18 %</td>
<td>2,323 MWh/building</td>
<td>164 MWh/m²</td>
<td>27</td>
</tr>
<tr>
<td>Median</td>
<td>53 MW</td>
<td>297 1000 m²</td>
<td>2.6 km</td>
<td>8 MW</td>
<td>50,000 MWh</td>
<td>14 %</td>
<td>1,840 MWh/building</td>
<td>164 MWh/m²</td>
<td>26</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.4 MW</td>
<td>3 1000 m²</td>
<td>0.1 km</td>
<td>0.16 MW</td>
<td>71 MWh</td>
<td>0 %</td>
<td>0.7 MWh/building</td>
<td>7.0 MWh/m²</td>
<td>0.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>600 MW</td>
<td>4,182 1000 m²</td>
<td>20.0 km</td>
<td>375 MW</td>
<td>910,000 MWh</td>
<td>65 %</td>
<td>9,000 MWh/building</td>
<td>392 MWh/m²</td>
<td>62</td>
</tr>
<tr>
<td>Sum total</td>
<td>3,559 MW</td>
<td>22,925 1000 m²</td>
<td>152.9 km</td>
<td>1,614 MW</td>
<td>3,964,217 MWh</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Number of responses (n)</td>
<td>27</td>
<td>24</td>
<td>25</td>
<td>26</td>
<td>27</td>
<td>26</td>
<td>27</td>
<td>24</td>
<td>19</td>
</tr>
</tbody>
</table>

*Inferred from questionnaire results

### Table A2: Physical and operating characteristics for heating (water) systems

<table>
<thead>
<tr>
<th>Units</th>
<th>Installed thermal capacity</th>
<th>Approximate building area served by hot water</th>
<th>Trench length of hot water network</th>
<th>Peak load of hot water system</th>
<th>Thermal energy supplied by hot water in 2014</th>
<th>Implied capacity factor*</th>
<th>Energy supplied per building*</th>
<th>Energy supplied per m²*</th>
<th>Linear heat density*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>14 MW</td>
<td>155 1000 m²</td>
<td>2.8 km</td>
<td>6 MW</td>
<td>18,211 MWh</td>
<td>16 %</td>
<td>1,517 MWh/building</td>
<td>239 MWh/m²</td>
<td>11</td>
</tr>
<tr>
<td>Median</td>
<td>5 MW</td>
<td>38 1000 m²</td>
<td>1.4 km</td>
<td>2 MW</td>
<td>4,800 MWh</td>
<td>15 %</td>
<td>717 MWh/building</td>
<td>113 MWh/m²</td>
<td>4</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.0 MW</td>
<td>2 1000 m²</td>
<td>0.1 km</td>
<td>0.60 MW</td>
<td>380 MWh</td>
<td>0.4 %</td>
<td>4.4 MWh/building</td>
<td>5.0 MWh/m²</td>
<td>0.3</td>
</tr>
<tr>
<td>Maximum</td>
<td>154 MW</td>
<td>1,700 1000 m²</td>
<td>22.0 km</td>
<td>58 MW</td>
<td>250,000 MWh</td>
<td>61 %</td>
<td>24,464 MWh/building</td>
<td>4,407 MWh/m²</td>
<td>122</td>
</tr>
<tr>
<td>Sum total</td>
<td>661 MW</td>
<td>6,982 1000 m²</td>
<td>135.3 km</td>
<td>271 MW</td>
<td>819,496 MWh</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Number of responses (n)</td>
<td>44</td>
<td>42</td>
<td>45</td>
<td>40 MW</td>
<td>40 MWh</td>
<td>35 %</td>
<td>40 MWh/building</td>
<td>35 MWh/m²</td>
<td>22</td>
</tr>
</tbody>
</table>

* Inferred from questionnaire results
Table A3: Physical and operating characteristics for cooling systems

<table>
<thead>
<tr>
<th>Units</th>
<th>Installed thermal capacity</th>
<th>Approximate building area served by cooling</th>
<th>Trench length of cooling network</th>
<th>Peak load of cooling system</th>
<th>Thermal energy supplied by cooling in 2014</th>
<th>Implied capacity factor*</th>
<th>Energy supplied per building*</th>
<th>Energy supplied per m²*</th>
<th>Linear cooling density*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>25</td>
<td>379</td>
<td>3.2</td>
<td>19</td>
<td>34,137</td>
<td>11</td>
<td>950</td>
<td>49</td>
<td>10</td>
</tr>
<tr>
<td>Median</td>
<td>6</td>
<td>70</td>
<td>1.6</td>
<td>4</td>
<td>3,216</td>
<td>9</td>
<td>665</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.4</td>
<td>0</td>
<td>0.1</td>
<td>0.20</td>
<td>369</td>
<td>2.1</td>
<td>1.4</td>
<td>1.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Maximum</td>
<td>229</td>
<td>3,717</td>
<td>22.0</td>
<td>220</td>
<td>383,000</td>
<td>25</td>
<td>3,570</td>
<td>130</td>
<td>26</td>
</tr>
<tr>
<td>Sum total</td>
<td>1,069</td>
<td>15,149</td>
<td>134.8</td>
<td>675</td>
<td>1,160,652</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Number of responses (n)</td>
<td>35</td>
<td>32</td>
<td>33</td>
<td>28</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>24</td>
<td>16</td>
</tr>
</tbody>
</table>

* Inferred from questionnaire results.

Table A4: Physical and operating characteristics for combined heat and power systems

<table>
<thead>
<tr>
<th>Units</th>
<th>Number of CHP engines/units on your system</th>
<th>Installed electrical capacity</th>
<th>Total quantity of electricity generated by CHP in 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>2</td>
<td>6</td>
<td>18,563</td>
</tr>
<tr>
<td>Median</td>
<td>1</td>
<td>5</td>
<td>400</td>
</tr>
<tr>
<td>Minimum</td>
<td>1</td>
<td>1.2</td>
<td>15</td>
</tr>
<tr>
<td>Maximum</td>
<td>6</td>
<td>21</td>
<td>99,379</td>
</tr>
<tr>
<td>Sum total</td>
<td>35</td>
<td>125</td>
<td>278,440</td>
</tr>
<tr>
<td>Number of responses (n)</td>
<td>15</td>
<td>15</td>
<td>10</td>
</tr>
</tbody>
</table>